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This report presents the feasibility for demonstration of the effectiveness of debris basins in controlling solids in water discharging from surface mine operations. Two sites in Eastern Kentucky were selected for study in areas where very little erosion-causing activity has occurred and where surface mining is to be initiated. Adjacent "virgin" watersheds were also selected for each study site to provide background data on water quality where man's activities have been very limited. Pertinent site information including flow and water quality data was gathered.

This study indicates the necessity for conducting the demonstration and develops a recommended procedure.

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DEBRIS BASINS FOR CONTROL OF SURFACE MINE SEDIMENTATION

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the pollutional impact on our environment and even on our health often requires that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-CI) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report discusses the feasibility and effectiveness of debris basins for controlling suspended solids in water discharging from surface mine operations. Two sites in Eastern Kentucky were selected for study. These are in areas where very little erosion-causing activity has occurred and where surface mining is to be initiated. The information contained herein characterizes the study sites and relates the current water quality. It is intended as a guide for future work, and is the planning document for use by the Commonwealth of Kentucky in continuing the demonstration. In addition, the information will be of use to other federal agencies and universities working in the eastern Kentucky region. The work repeated here complements other sedimentation studies of the Extraction Technology Branch of IERL-CI.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

This report presents the feasibility for demonstration of the effectiveness of debris basins in controlling solids in water discharging from surface mine operations. Two sites in Eastern Kentucky were selected for study in areas where very little erosion-causing activity has occurred and where surface mining is to be initiated. Adjacent "virgin" watersheds were also selected for each study site to provide background data on water quality where man's activities have been very limited. Pertinent site information including flow and water quality data were gathered. Cooperation agreements were signed by the various mining companies assuring access and data availability. Several potential study areas were eliminated for various reasons, leaving the remaining two watersheds, Dicks Fork and Rhoades Branch.

These watersheds proved to be acceptable sites for the demonstration of the feasibility of debris basins in controlling water pollution.

This study indicates the necessity for conducting the demonstration and develops a recommended procedure.

This report was submitted by the Kentucky Department for Natural Resources and Conservation in fulfillment of E.P.A. Project S-801276 under the partial sponsorship of the U.S. Environmental Protection Agency. This report of work, subcontracted to L. Robert Kimball, Consulting Engineers, Ebensburg, Pennsylvania, was completed as of June 1974.

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PREFACE

Subsequent to the preparation of this report, site number one, Crescent Coal Company, has been eliminated from consideration as a demonstration site pending the results of legal proceedings between Crescent Coal Company and the United States Army Corps of Engineers.

In order to maintain continuity in the report, and should the site re-enter consideration, all data collected and all references made to this site are retained in the report. However, consideration of site number one for the demonstration was not included in the Conclusions and Recommendations reached in this report.

ACKNOWLEDGEMENTS

The advice and guidance of Messrs. Robert E. Nickel and William Kelly of the Office of Planning and Research, Kentucky Department for Natural Resources and Environmental Protection are sincerely appreciated.

Mr. Calvin Tackett of the Tackett and Manning Coal Corporation and Mr. Donald Johnson of the Crescent Coal Company supplied valuable data and excellent cooperation during the investigation portion of this study.

The support of the project by Mr. John Martin, Project Officer, Mining Pollution Control Branch, Office of Research and Development, Environmental Protection Agency is acknowledged with sincere gratitude.

SECTION I

CONCLUSIONS

The demonstration of debris basin effectiveness is feasible at the site selected and will yield vital information concerning the adequacy of existing regulations governing discharges from active surface mining operations.

Demonstration of debris basin feasibility should be conducted as soon as possible because of increasing surface mining and the diminishing ability of the local environment to assimilate further excessive volumes of sediment.

The extensive stream bottom sediment shifting monitoring during this study phase indicates that discharges of the debris basins during the demonstration phase should be determined by concrete weir placement to provide long term stability for accurate measurement as well as uniform sampling conditions.

Precise correlation of precipitation and sediment discharge is not necessary for the purposes of this demonstration and would require extensive effort beyond the present scope of work.

SECTION II

RECOMMENDATIONS

It is recommended that demonstration of the feasibility of debris basins be conducted according to the procedures outlined below:

1. Debris basins should be constructed according to existing regulations. The basins should be inspected continually during construction and all unusual or significant conditions should be noted.

2. Concurrent with debris basin construction, automatic monitoring stations should be installed, calibrated, and checked for proper function. The debris basin construction period, approximately one month, will allow time to "de-bug" the monitoring systems as well as furnish additicnal background information. Continuing grab sample collection will also provide transitional data.

3. During the actual surface mining of the area, visual inspections of the study site should be made and observations recorded to supplement the automatic monitoring data. In addition, functioning of the automatic monitoring stations should be checked and "grab" samples obtained according to the schedule presented in the discussion section of this report.

4. Monthly inspections during the progress of mining should accurately determine areas of active mining, backfilling, and revegetation. This should be supplemented by yearly aerial photographic reconnaissance.

5. Upon completion of surface mining, monitoring of the study stream should continue until such a time as water quality monitoring and visual inspection of the site indicate that water quality stability has been achieved.

6. The adequacy of existing regulations should be reviewed in terms of the data obtained during the demonstration. If necessary, recommendations should be developed to improve debris basin designs to achieve the desired water quality levels.

It is recommended that the demonstration proceed as quickly as possible because of the ever increasing amount of surface mining caused by the growing demand of coal. The possibility of placing a severe strain upon the environment cannot be evaluated or controlled until effectiveness of debris basins in controlling sedimentation is established.

In view of the various problems experienced to date in the site selection, it is recommended that if either or both of the sites under consideration in this report are not available for the demonstration, other sites be chosen according to the site selection criteria contained in this report. It is possible to utilize sites which are currently being surface mined and have debris basins constructed according to current regulations. The sites would be selected in small, relatively undisturbed watersheds where current surface mining is the only activity. The efficiency of debris basins in controlling sedimentation is determined by the difference in water quality upstream and downstream of the debris basins. The sampling station downstream from the debris basins will document the efficiency when compared to the data obtained at the upstream station. An adjacent, similar "virgin" watershed would be selected for monitoring as a further control on background water quality.

The other goals of the demonstration such as determining the cost and construction methods could be achieved after construction. Field investigation of the basins will yield sufficient data to develop "as built" construction costs using standard methods, final capacity, and suitability of construction.

The benefits of the demonstration are too important to abandon this effort should the preselected sites become unsuitable. Many more debris basins are being constructed as surface mining continues to be favored over deep mining and as coal demand increases. The effectiveness of debris basins should be established, followed by the development of new design and construction criteria should the existing criteria be found inadequate.

SECTION III

INTRODUCTION

PURPOSE AND SCOPE OF WORK

The purpose of this report is to evaluate the feasibility of conducting a demonstration of the effectiveness of debris basins in controlling sediment from surface mining using design regulations currently required by the Commonwealth of Kentucky.

This study is the second step in the demonstration program, being preceeded by a pre-feasibility study submitted by L. Robert Kimball, Consulting Engineers, in March 1972, to the Division of Reclamation, Department for Natural Resources and Environmental Protection, Commonwealth of Kentucky.

The funding for this study is provided by the United States Environmental Protection Agency, Office of Research and Development, while the administration is the responsibility of the Commonwealth of Kentucky Department of Natural Resources and Environmental Protection, Office of Planning and Research.

A guide for the preparation of such studies was prepared by the Federal Water Quality Administration titled "Feasibility Study Manual - Mine Water Pollution Control Demonstrations."

In addition to this project, the Commonwealth is initiating a study program titled "Research and Demonstration of Improved Surface Mining Techniques in Eastern Kentucky", in an agreement with the Appalachian Regional Commission. Currently, this proposed program consists of the following six (6) tasks: (1) Design of Surface Mining Systems; (2) The Economic, Environmental and Physical Evaluation of Selected Surface Mining Techniques; (3) Sediment Control Research; (4) slope Stability; (5) Revegetation; and (6) Water Quality Research.

Upon receiving grant approval for this study of sediment control, step (3) from the above program was deleted to avoid overlapping study subjects.

BACKGROUND

Kentucky coals occur in two major coal fields--the Eastern Kentucky Coal Field and the Western Kentucky Coal Field. The Eastern Coal Field was selected for this study to demonstrate the effectiveness of sediment control debris basins designed and constructed in accordance with the engineering standards developed by the Kentucky Soil Conservation Service. An important factor in selecting the Eastern Coal Field is its steeply-sloping terrain which causes rapid runoff of surface water, intensifying erosion in disturbed areas.

Hilltop elevations range from 305 meters (1,000 feet) in the northeast to 1158 meters (3,800 feet) in the southeast. Local relief similarly varies from 152 meters (500 feet) to greater than 610 meters (2,000 feet). The topography in the western field however, is composed of more gently rolling terrain that is less susceptible to erosion.

The Eastern Region is drained by the Big Sandy River, Little Sandy River, Tygart's Creek, Licking River, Kentucky River and Cumberland River.

The jurisdictional framework and authority for this project lies with Kentucky Division for Natural Resources and Environmental Protection and is presented in Appendix A.

OBJECTIVES

In order to determine if the data to be obtained from the demonstration will be adequate to determine the efficiency of debris basins, a five month study was undertaken. Individual items addressed in the study were:

1. Selection of an alternate site to replace that of the Marty Corporation (proposed in the grant application);

2. Mapping of the sites by aerial photogrammetric means to establish premining topography;

3. Collection and testing of soil samples to supplement published information;

4. Collection and analysis of water samples every two weeks and during a significant precipitation event to determine background water quality in the undisturbed drainage basins;

5. Collection of flow and precipitation data every two weeks to characterize the natural system hydrology;

6. Selection of monitoring equipment and design of the monitoring stations and;

7. Review of published information pertinent to all phases.

SECTION IV

SITE SELECTION

The criteria for site selection, in order of importance, are as follows:

1. The availability of a control watershed;
2. Determination that the data collected from the site will be adequate for the demonstration;
3. No previous surface mining within the watershed;
4. No recent evidence of timbering or other disruption;
5. Availability of an agreement with the coal operator to coordinate the project with mining operations;
6. Access to the site and its effect on the project; and
7. Proximity of electrical power for monitoring equipment.

SITE EVALUATION

Two sites were chosen which best satisfy the site selection criteria: Dicks fork, located in an area to be surface mined by the Crescent Coal Company, and Rhoades Branch, located in an area to be surface mined by the Tackett and Manning Coal Company (Figure 1). Control streams were chosen for each site in order to provide a reference base for data obtained during the demonstration. As a necessary condition of the controls, no mining or other activities will be conducted on the control streams during the course of the demonstration.

CRESCENT COAL COMPANY SITE

Dicks Fork

The Dicks Fork watershed is located east of Pikeville in Pike County in the northwest quadrant of the Lick Creek, Kentucky 7.5 Minute Topographic Quadrangle (Figure 2). Access to the site is provided by a lane running north from its intersection with Route 194 on the west side of the Phyllis Post Office.

The watershed consists of approximately 162 hectares (400 acres) upstream from the proposed downstream monitoring location. Old logging trails are present on the hillsides; and a sawmill was once present in the upper reaches of Dicks Fork, as evidenced by wood shavings, slashings and old sawdust piles. Second growth trees cover ninety (90) percent of the area. Five gas wells are also within the watershed.

Figure I. STUDY SITES IN EASTERN KENTUCKY

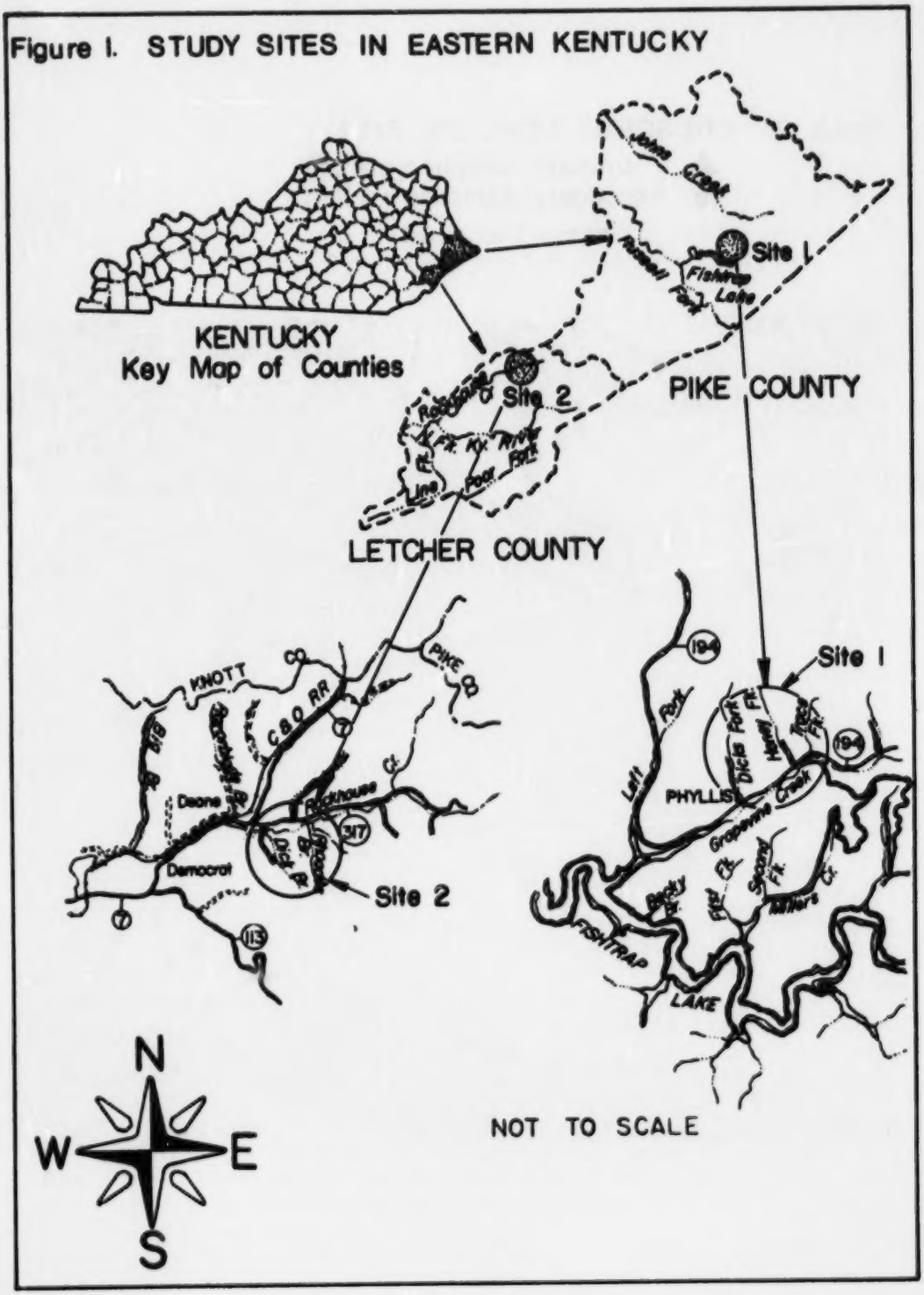
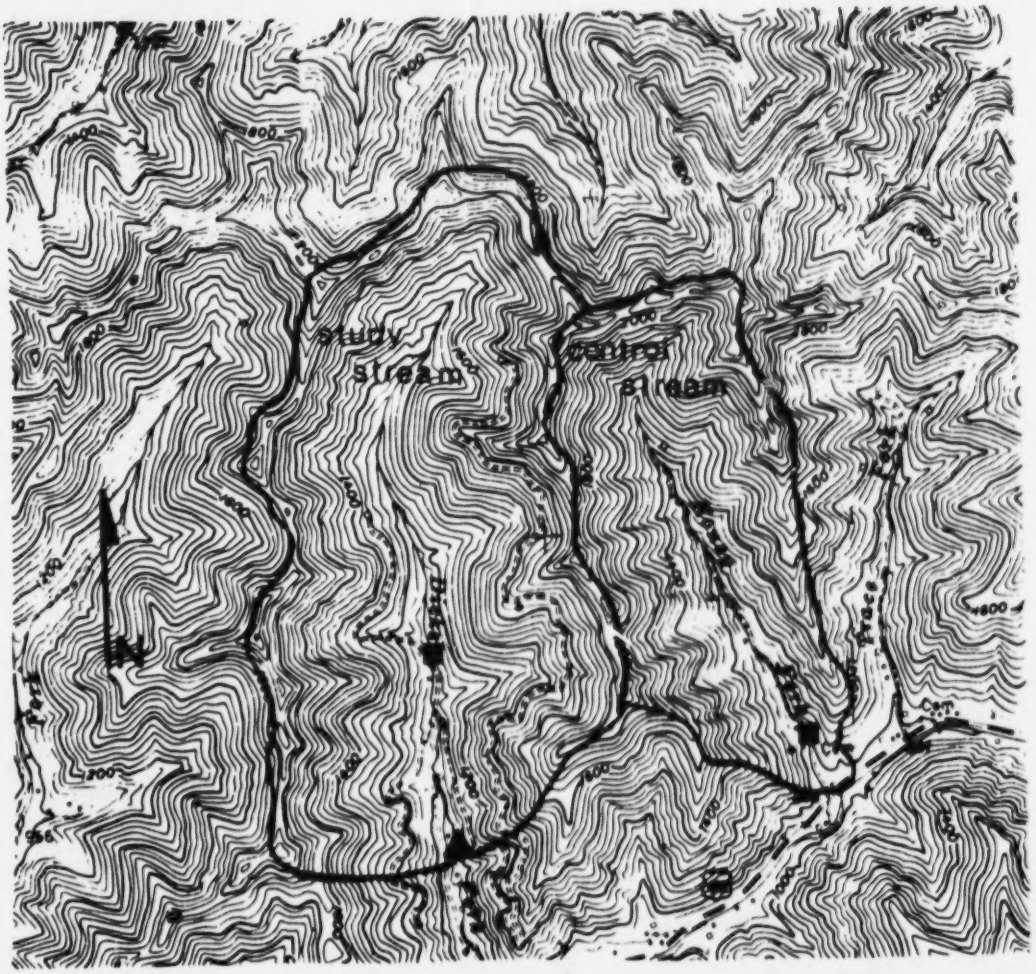


Figure 2. CRESCENT COAL CO. SITE

▲ primary sampling station

■ secondary sampling station

scale 1"= 2000'



Ridge top elevations bounding the watershed range from 560 m (1836 feet) to 661 m (2168 feet). Hillside slopes range from 30% (17°) to 65% (33°). Dicks Fork, 2970 m (9740 feet) long, begins as intermittent springs at approximate elevation 495 m (1625 feet) and flows out of the valley at elevation 268 m (880 feet). The overall gradient of the stream is 7.5%.

Ten coal seams in eight coal zones are exposed in outcrops within the watershed. In ascending order these are the Clintwood, elevation 305 m (1,000 feet); Lower Elkhorn, elevation 366 m (1,200 feet); a coal bed in the Upper Elkhorn No. 3 Coal zone, elevation 425 m (1,600 feet); three coal beds in the Fire-Clay-Whitesburg coal zone, elevation 524 m (1,720 feet) 537 m (1,760 feet), and 595 m (1,950 feet). The Taylor coal bed is exposed on the highest knobs at elevation 622 m (2,040).

Honey Fork - Control Stream for Dicks Fork

Honey Fork is located in the large hollow immediately to the east of Dicks Fork (Figure 2). Access to the stream is provided by Kentucky Route 194 (old U.S. Route 460) and a lane to the north from an intersection with Route 194 to the west of the Grapevine Elementary School.

The watershed consists of approximately 131 hectares (324 acres) upstream from the proposed monitoring location. Three gas wells with their attendant access roads are in the area. More than ninety (90) percent of the area is forested.

Ridge top elevations bounding the watershed range from 418 m (1,370 feet) to 670 m (2,196 feet). Hillside slopes range from 30% (17°) to 75% (37°). Honey Fork, 1951 m (6,400 feet) long, begins as intermittent springs at approximate elevation 564 m (1,850 feet) and flows out of the valley at elevation 300 m (985 feet). The overall gradient of the stream is 14%.

Two caved mine entries are present in this area, one in the Clintwood seam, elevation 305 m (1,000 feet) and one in the Lower Elkhorn seam, elevation 366 m (1,200 feet).

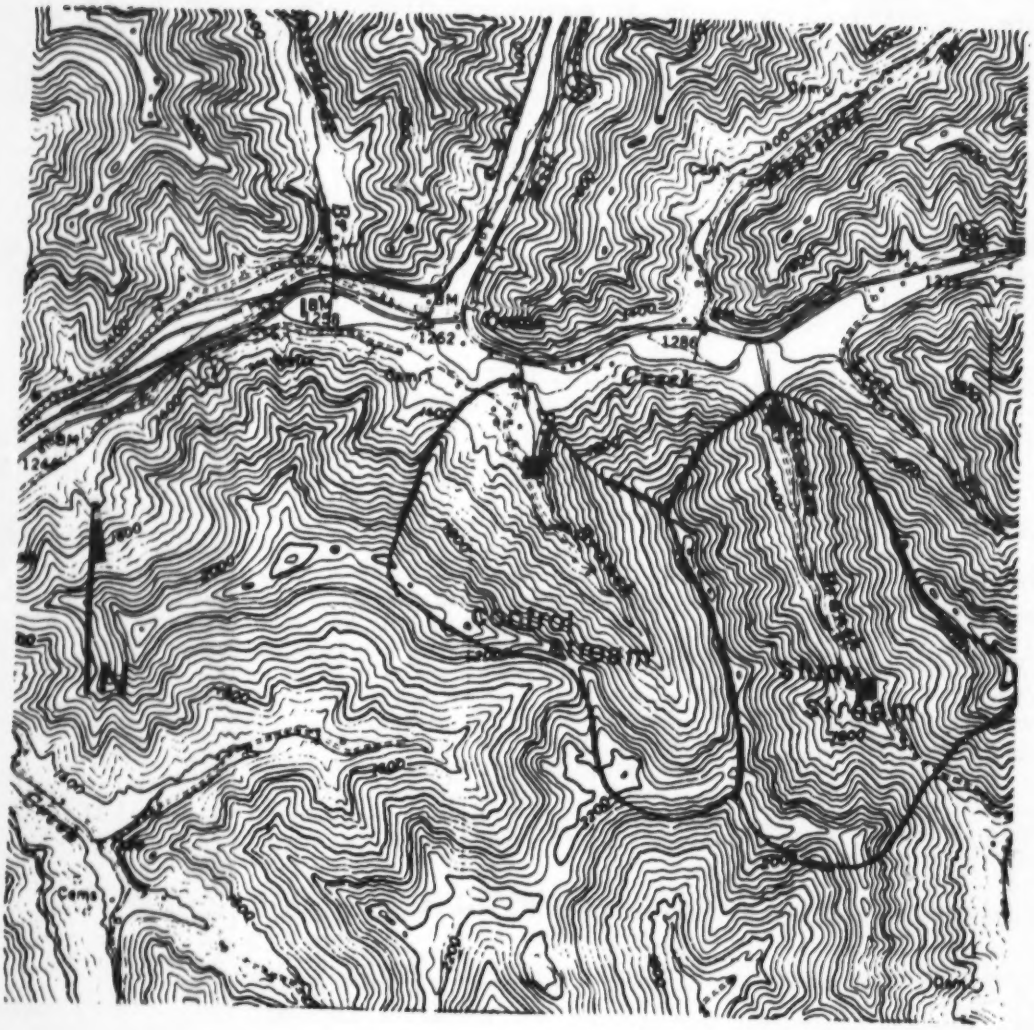
This area contains the same coal outcrops as reported for the Dicks Fork area.

TACKETT AND MANNING COAL COMPANY SITE

Rhoades Branch

The Rhoades Branch watershed is located in Letcher County east of Deane, in the northeast quadrant of the Mayking, Kentucky 7.5 Minute Topographic Quadrange (Figure 3). Access to the site is provided by Kentucky Route 275 in the valley of Rockhouse Creek and an abandoned country road south from an intersection with Route 275 approximately 853 m (2,800 feet) east of the intersection of Kentucky Route 7. This site was se-

Figure 3. TACKETT AND MANNING COAL CO. SITE
▲ primary sampling station
■ secondary sampling station
scale 1"= 2000'



lected to replace the Marty Corporation site (Site 2 in the Pre-Feasibility Report).

The watershed consists of approximately 113 hectares (280 acres) upstream from the proposed monitoring location. An abandoned deep mine is present near the valley mouth in the Upper Elkhorn No. 3 coal zone. An abandoned loading tipple is present in the upper reaches of the valley in the Amburgy coal zone. Second growth trees cover ninety (90) percent of the area.

Ridge top elevations bounding the watershed range from 581 m (1,906 feet) to 683 m (2,240 feet). Hillside slopes range from 15% (14°) to 71% (36°). Rhoades Branch 1525 m (5,000 feet) long begins as intermittent springs at approximate elevation 531 m (1,700 feet) and flows out of the valley at elevation 390 m (1,280 feet). The overall gradient of the stream is 8.6%.

A total of three coal seams in three coal zones are exposed as outcrops within the watershed. In ascending order these are a coal bed in the Upper Elkhorn No. 3 coal zone, elevation 425 m (1,400 feet); Amburgy coal, elevation 485 m (1,590 feet); and the Fire Clay coal zone, elevation 549 m (1,800 feet).

Dick Branch - Control Stream for Rhoades Branch

Dick Branch is located in the large hollow immediately to the west of Rhoades Branch. Access to the stream is provided by Kentucky Route 7.

The watershed consists of approximately 95 hectares (324 acres) upstream from the proposed monitoring location. More than ninety (90) percent of the area is forested. Ridge top elevations bounding the watershed range from 604 m (1,980 feet) to 683 m (2,240 feet).

Hillside slopes range from 25% (14°) to 71% (36°). Dick Branch 1463 m (4,800 feet) long, begins as intermittent springs at approximate elevation 482 m (1,280 feet) and flows out of the valley at elevation 298 m (987 feet). The overall gradient of the stream is 6.3%.

This area contains the same coal outcrops as reported for the Rhoades Branch watershed.

SECTION V

MONITORING AND SAMPLING

MONITORING

Stream discharge monitoring stations were established concurrently with the downstream sampling points on Dicks Fork and Rhoades Branch. Sampling stations were also established at upstream points on Dicks Fork and Rhoades Branch relative to the proposed debris basin locations and near the mouths of the control streams. Approximate locations and designations of sampling and discharge monitoring points are shown on Figures 2 and 3.

Discharges of the study streams were determined by measuring the cross ssections of the stream bed, the depth of the water, and using the "float" method of measuring velocity as described in the Water Measurement Manual.

Stream discharges were measured at two week intervals and once during a significant precipitation event.

The study stream discharge measurements are presented in Appendix B, Tables 7 and 9 and a summary is presented in the discussion section.

SAMPLING

Water samples for chemical analysis were taken at the upstream and downstream sampling stations of the study streams and the proposed secondary monitoring station locations on the control streams. Samples were anaylzed by the Environmental Engineering Laboratory of L. Robert Kimball according to the American Public Health Association's (APHA) methods presented in Standard Methods for the Examination of Water and Wastewater. The various parameters, APHA designations, reporting units, and minimum detectable concentrations are shown in Table 1.

Table 1. METHODOLOGY FOR WATER QUALITY ANALYSIS

Parameter	APHA Designation	Reporting Units	Minimum Detectable Concentration
pH	#163	-----	-----
Turbidity	#144A	Jackson Turbidity Units	10.0 JTU
Total Alkalinity As $CaCO_3$	#102	Milligrams Per Liter (mg/l)	0.0 mg/l
Phenolphthalein Alkalinity	#102	mg/l	0.0 mg/l
Ca Hardness	#110C	mg/l	1.0 mg/l
$CaCO_3$ Hardness	#112B	mg/l	1.0 mg/l
Magnesium	#112A (Modified)	mg/l	1.0 mg/l
Iron	#124	mg/l	0.01 mg/l
Manganese	#128C (Modified)	mg/l	0.02 mg/l
Sulfate	#156C (Modified)	mg/l	0.0 mg/l
Total Hot Acidity (As $CaCO_3$ Equivalents)	#101	mg/l	0.0 mg/l
Free Acidity (As $CaCO_3$ Equivalents)	#101	mg/l	0.0 mg/l
Conductivity	#154	Micromhos/ Centimeter	0.0 MHOS/cm
Settleable Solids	#224F	Milliliters/ Liter (ml/l)	0.5 ml/l
Suspended Solids	#148B (Modified)	mg/l	0.0 mg/l

Table 1. (continued) METHODOLOGY FOR WATER QUALITY ANALYSES

Parameter	APHA Designation	Reporting Units	Minimum Detectable Concentration
Dissolved Solids	#154 (Modified)	mg/l	0.0 mg/l
Total Solids	#148A (Modified)	mg/l	0.0 mg/l

The results of the water quality analyses are presented in Appendix B, Tables 6 through 11 and a summary is presented in the discussion section. Additional data was available for Dicks Fork downstream monitoring station and is presented with the results of the analyses.

The loading of total weight (expressed in kilograms per day) of each parameter carried by the study streams was determined according to the equation:

$$L = 1.44\ QA$$

where L = loading, Kg/day

Q = discharge, m^3/min

A = parameter, mg/l

The amount of a parameter expressed as loading in kilograms per day is used for expression of the background water quality because it is an absolute number which expresses the total amount of material passing the measuring point and may be converted to the amount of pollutants derived from any disturbed land unit. Loading data for Dicks Fork downstream and Rhoades Branch downstream is presented with the results of analyses in Appendix B, Tables 7 and 10.

Soil samples were taken in the watersheds using hand driven Shelby tube and analyzed in the Geotechnical Laboratory of L. Robert Kimball to determine the soil permeability and grain size distribution. The results of the analyses are presented in the discussion section.

PRECIPITATION

Two Belfort recording rain gauges were supplied through the Water Quality Office of the Environmental Protection Agency. These were positioned to supply detailed preciptation information for each site. A combination of equipment failure, vandalism, and natural damage prevented the generation of

of useful data from these gauges.

Precipitation data was then obtained from the Pikeville and Fishtrap stations of the United States Departmen of Commerce, National Oceanic and Atmospheric Administration and is presented in Table 2.

Table 2. PRECIPITATION FOR FEBRUARY - MAY 1974

	February		March		April		May	
	Fishtrap	Pikeville	Fishtrap	Pikeville	Fishtrap	Pikeville	Fishtrap	Pikeville
1			T					.17
2	.17	.85				.27		.46
3	.38	.01						.30
4	.02	T				1.19		
5	T		T			T		.20
6		.08	.28			.05		
7	.10	T	1.12					T
8	.20	.60	T			.52		.04
9	.22	T				.52		
10	T	T	.05					.06
11	.06		1.22					1.06
12			1.00					
13		.04	.60			.01		
14	.15	T				.12		
15								
16		.13	.38			.14		.06
17	.20		.27					.31
18			T					.32
19	.03	.31	.07					
20	.22	.08	.78					
21			1.05			T		.02
22	.22	.40	.30			.94		1.32
23	.09							T
24		.03	.12					
25	.14	T	T					
26	.02	T						
27								
28			T					.10
29								.40
30			.49					1.29
31			.18					
TOTAL	2.22	2.53	7.91			3.46		6.11

NOT REPORTED

T = Trace amount observed.

Data obtained from U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration Climatological Data, Kentucky

SECTION VI

DISCUSSION

DISCHARGE MEASUREMENT

Analysis of the stream cross section records shows the magnitude of variation which has occurred during the course of the study (Figures 4 and 5). These results indicate that it will be necessary to utilize a permanent flow measuring device for discharge monitoring to minimize the error resulting from shifting stream cross sections.

A summary of the study stream discharges is presented in Table 3.

Table 3. DISCHARGE SUMMARY
(m3/Min)

	Maximum	Minimum	Average	Precipitation Event
Dicks Fork	10.1	2.1	7.0	186.5
Rhoades Branch	11.7	2.0	5.3	111.5

As can be seen, the discharges for the precipitation event are extremely higher than the "maximum" discharge recorded during the project. These "precipitation event" discharges were not included in the averaging since a special effort was made to determine these flows during a specific period. These data indicate the inherent diversity of these discharges and provide the range of discharge values to be used in design of weirs.

WATER QUALITY SAMPLING

Loading data indicates that little erosion is occurring in either watershed and that both study streams in their natural state are relatively low solids producers. The relationship between discharge and total solids can be seen in Figures 6 and 7. The relationship is relatively well defined for Rhoades Branch in 0-8 m3/min discharge range and less defined for Dick Fork in the same range indicating slightly different hydrological conditions betwen the study streams. Additional data generated during the demonstration will further define this relationship.

SOILS

Random soil samples taken in the study areas indicate that residual soils (formed in place) and alluvial soils (deposited) within the area range from sandy loam to loam to silty loam, all with sandstone and/or shale fragments (Figures 8 and 9). It is assumed that the high rate of

Figure 4. STREAM BED SHIFTING FOR DICKS FORK

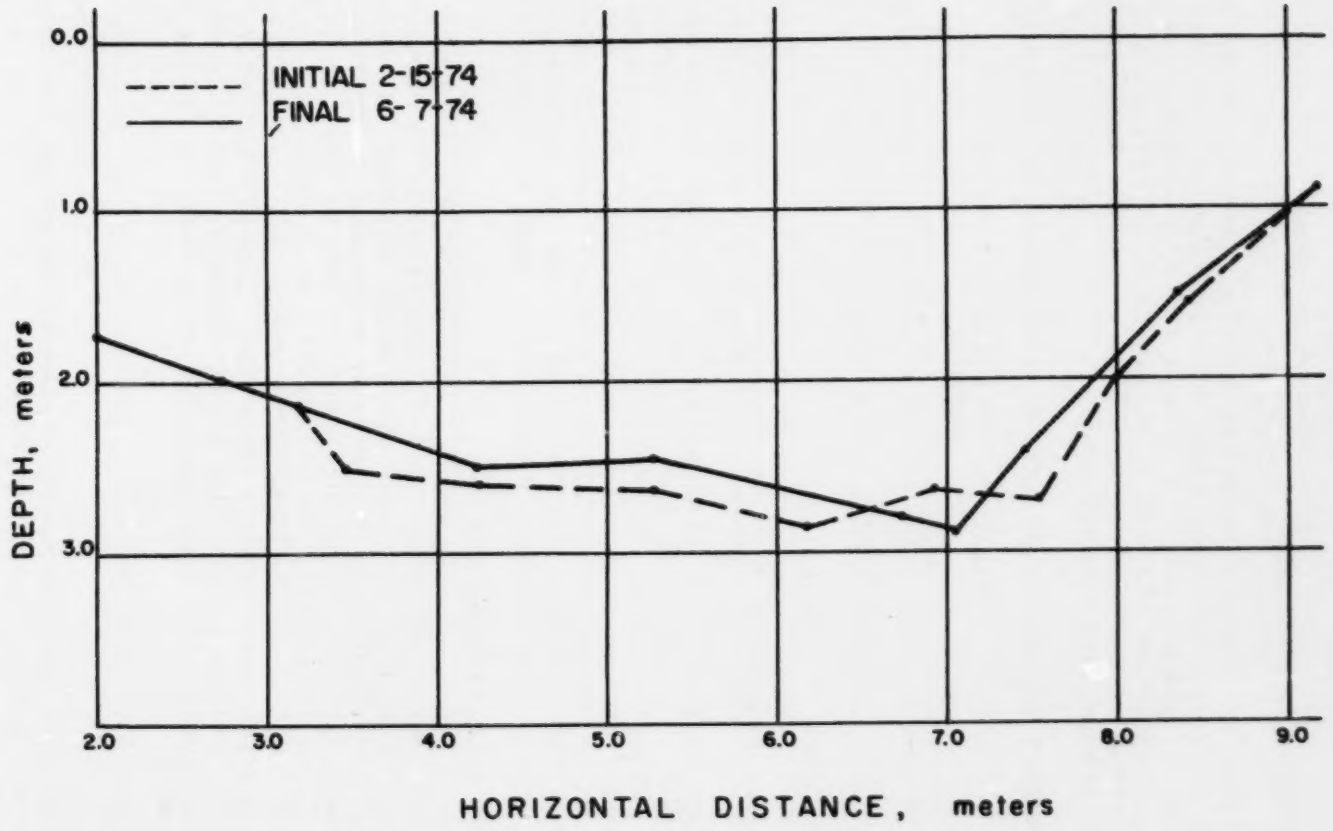


Figure 5. STREAM BED SHIFTING FOR RHOADES BRANCH

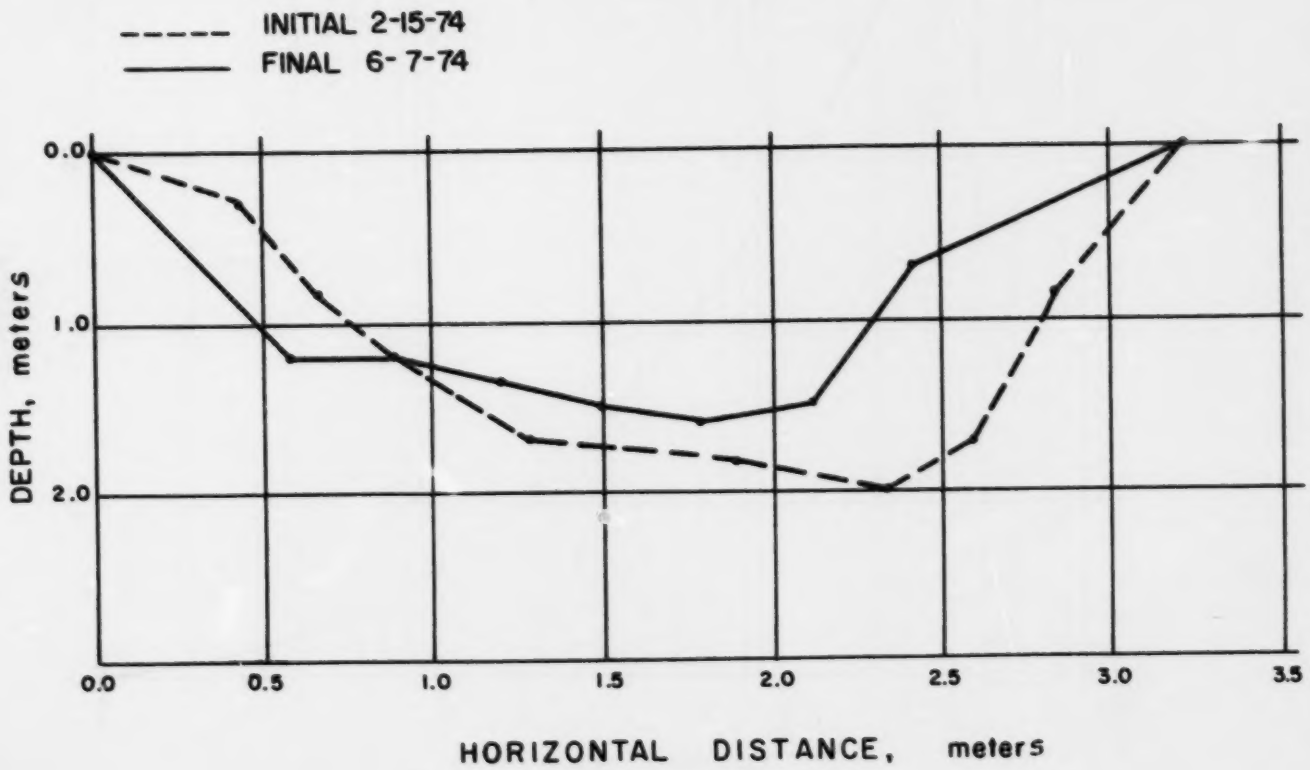


Figure 6. TOTAL SOLIDS vs. DISCHARGE FOR DICKS FORK

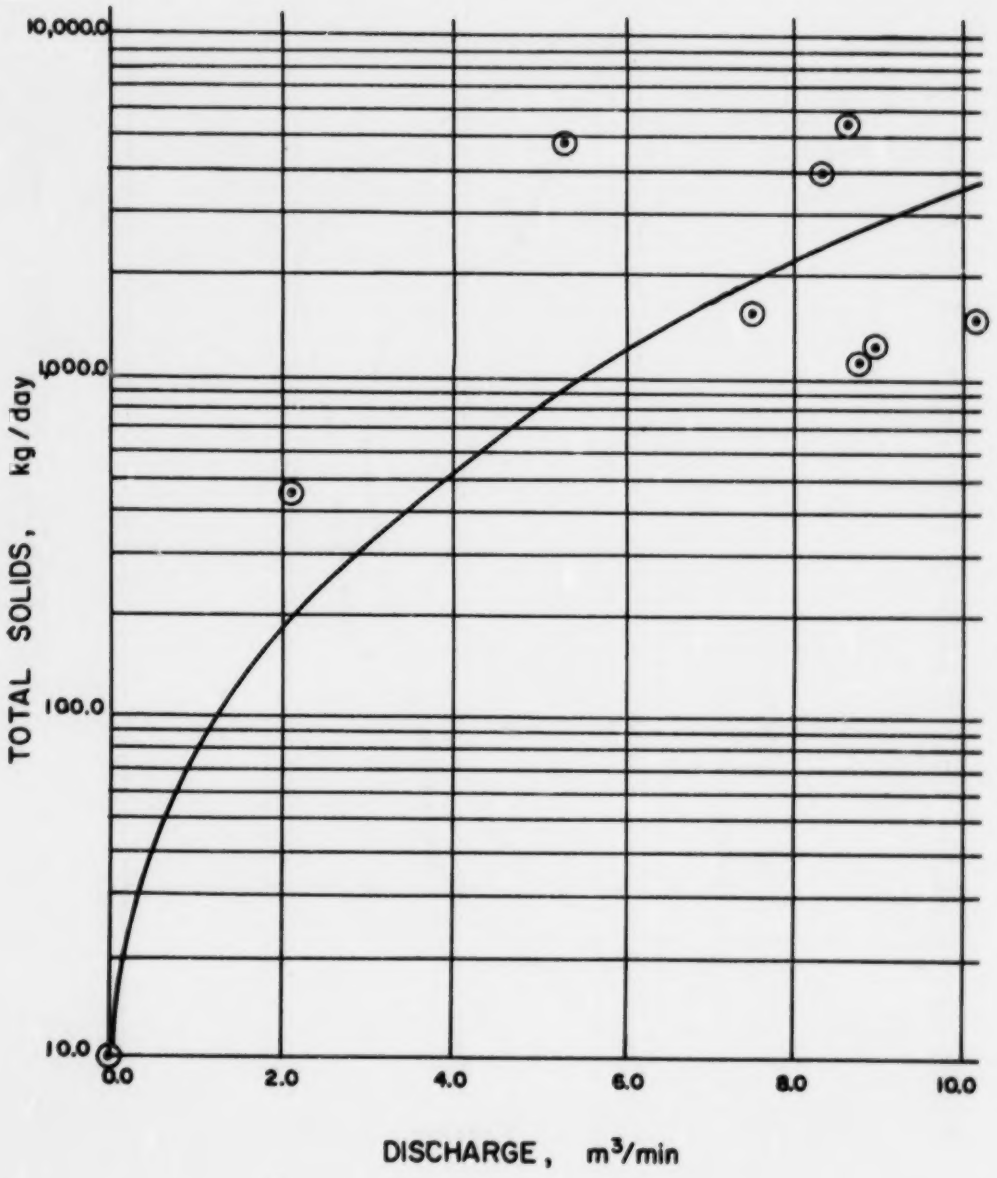
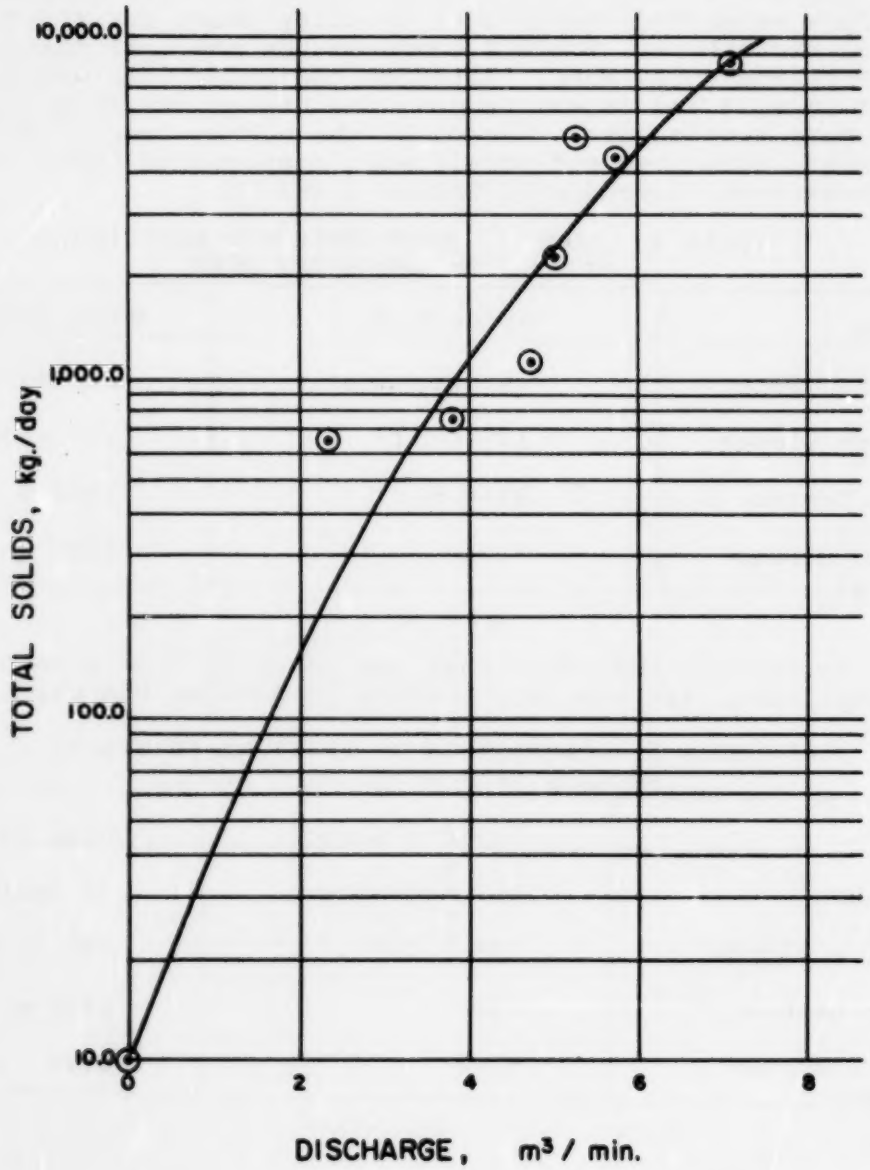


Figure 7. TOTAL SOLIDS vs DISCHARGE FOR RHOADES BRANCH



runoff is, to a large extent, the reason for the large amount (35 to 40 percent) of coarse fragments present in the two soil samples analyzed since fines tend to be carried off by severe runoff. (See figures 8 and 9 for grain size distribution curves.) The coefficients of permeability of both soil samples tested (Figures 10 and 11) averaged 1.1 meters per hour indicating well drained clean sand and gravel with very few fines.

Visual inspection and field testing indicated that soils in the Honey Fork watershed, sandy loam to silty loam, are similar to those of Dicks Fork. Table 4 compares the physical features of Dicks Fork and Honey Fork. Although the Honey Fork watershed is smaller in size and stream length, the higher stream gradient causes more erosion as evidenced by the higher average solids (suspended, dissolved and total) when compared to those of Dicks Fork downstream (Appendix B, Tables 7 and 8).

Table 4. COMPARISON OF PHYSICAL FEATURES: DICKS FORK AND HONEY FORK

Feature	Dicks Fork	Honey Fork
Watershed Size	161 hectares	131 hectares
Hillside Slopes	17° - 33°	17° - 37°
Stream Length	1970 m	1951 m
Overall Stream Gradient	7.5%	14%

Visual inspection indicates that the soils in Dick Branch, loams to silty loams, are similar to those of Rhoades Branch.

Table 5. COMPARISON OF PHYSICAL FEATURES: RHOADES BRANCH AND DICK BRANCH

Feature	Rhoades Branch	Dick Branch
Watershed	113 hectares	95 hectares
Hillside Slopes	14° - 36°	14° - 36°
Stream Length	1525 m	1436 m
Overall Stream Gradient	8.6%	6.3%

Figure 8. GRAIN SIZE DISTRIBUTION CURVE
DICKS FORK WATERSHED

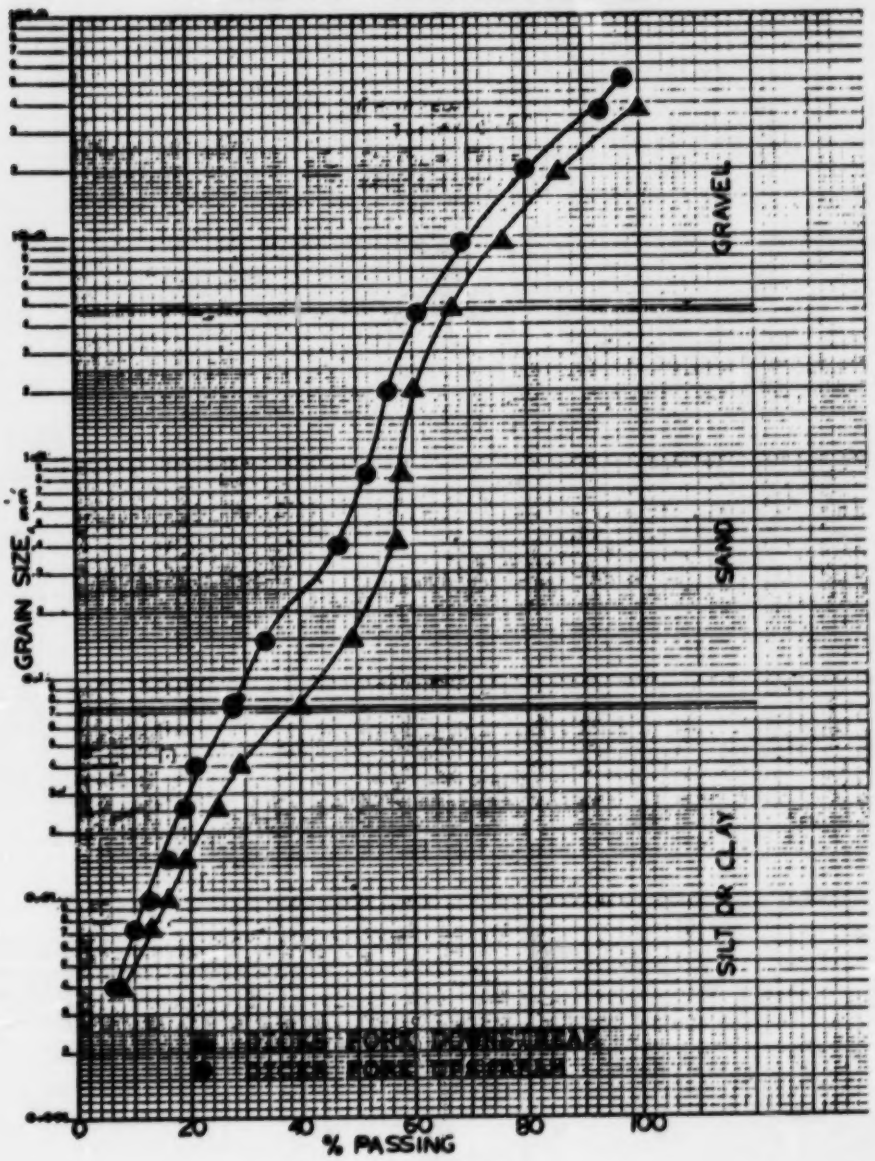


Figure 9. GRAIN SIZE DISTRIBUTION CURVE
RHOADES BRANCH WATERSHED

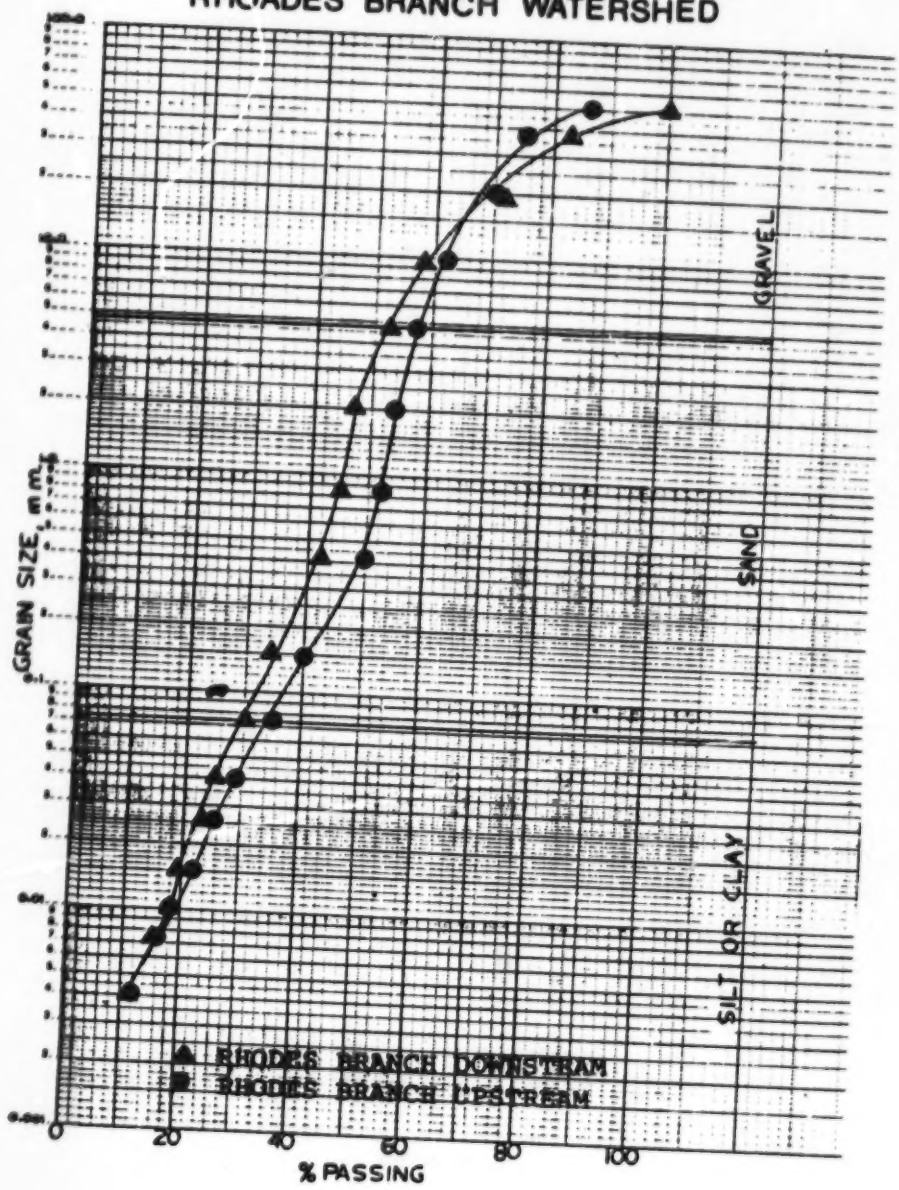


Figure 10. SOIL PERMEABILITY- DICKS FORK WATERSHED

Sample # Dick's Fork ST#1 Name KY/EPA

Job # E-74-2 Date 2/28/74

Initial container + sample wt. 3121.0 g Head (h) in cm 116.4

Container wt. 1306.3 g Temp of water (°C) 19.0°

Sample wt. 1814.7 g Hydraulic Gradient (i) 3.95

Initial Moisture Content 11.33 % $i = \frac{h}{L}$

Dry Sample wt. 1630.0 g

Sample Dimensions:

Length (L) 29.50 cm Area (A) 41.38 cm^2

Dia. 7.26 cm Volume (V) 1220.71 cm^2

Elapsed Time (sec)	Quantity (cc)	K T cm/sec	K 20 cm/sec	Remarks
5.0	25.0	3.06×10^{-2}	3.06×10^{-2}	Discharge cloudy
10.0	53.0	3.24×10^{-2}	3.24×10^{-2}	Discharge cloudy
15.0	79.0	3.22×10^{-2}	3.22×10^{-2}	Discharge clear
20.0	101.0	3.09×10^{-2}	3.09×10^{-2}	Discharge clear

$$k_T = \frac{Q}{IAT}$$

k_T = 3.15×10^{-2} cm/sec = 1.1 meters/hr.

Initial Moisture Content

Pan #	165
Wet wt + tare	352.1
Dry wt + tare	324.2
Wt of water	27.9
Tare wt	77.9
Wt of Dry Soil	246.3
% Moisture	11.33%

Final Moisture Content

Pan #	III
Wet wt + tare	2261.0
Dry wt + tare	1839.5
Wt of water	421.5
Tare wt	211.8
Wt of Dry Soil	1627.7
% Moisture	25.90%

Figure II. SOIL PERMEABILITY - RHOADES BRANCH WATERSHED

Sample # Rhoades Branch ST#2 Name KY-EPA

Job # R-74-2 Date 2/20/74

Initial container + sample wt. 3333.0 g Head (h) in cm 102.4

Container wt. 1582.4 g Temp of water (°C) 18°C

Sample wt. 1750.6 g Hydraulic Gradient (i) 3.16

Initial Moisture Content 13.20% $i=\frac{h}{L}$

Dry Sample wt. 1547.5 g

Sample Dimensions:

Length (L) 32.40 cm Area (A) 45.15 cm^2

Dia. 7.24 cm Volume (V) 1333.19 cm^2

Elapsed Time (sec)	Quantity (cc)	K T cm/sec	K 20 cm/sec	Remarks
5.0	23.0	3.52×10^{-2}	3.52×10^{-2}	Discharge cloudy
10.0	41.5	3.17×10^{-2}	3.19×10^{-2}	Discharge clear
15.0	59.0	3.01×10^{-2}	3.01×10^{-2}	Discharge clear
20.0	75.0	2.87×10^{-2}	2.87×10^{-2}	Discharge clear

$$k_T = \frac{Q}{IAT}$$

$k_T = 3.09 \times 10^{-2}$ cm/sec = 1.1 meters/hr.

Initial Moisture Content

Pan #	138
Wet wt + tare	354.6
Dry wt + tare	322.5
Wt of water	32.1
Tare wt	78.9
Wt of Dry Soil	243.6
% Moisture	13.20%

Final Moisture Content

Pan #	II
Wet wt + tare	2122.7
Dry wt + tare	1765.0
Wt of water	357.7
Tare wt	247.8
Wt of Dry Soil	1517.2
% Moisture	23.58%

As evidenced by the preceeding comparisons, either site, together with its respective control stream, proves to be satisfactory for the purpose of this demonstration. Figures 12 and 13 show the correlation observed between each study stream and its control for total solids throughout the course of this study. This correlation permits valid comparison between the control streams and the study streams during the demonstration.

PRECIPITATION

An attempt was made to correlate discharges and precipitation for the study streams but, because of the large number of variables involved, was abandoned as being beyond the scope of this project. It was learned that total precipitation per time period is not sufficient unless other pertinent conditions are noted such as vegetation, slope, etc. and unless the stream discharge is being continuously monitored. Furthermore, it appears that the benefit of such correlation, the prediction of solids concentration based on precipitation, is not of sufficient value to merit the additional effort and expense required.

Figure 12. VARIATION OF DICKS FORK COMPARED TO HONEY FORK FOR TOTAL SOLIDS

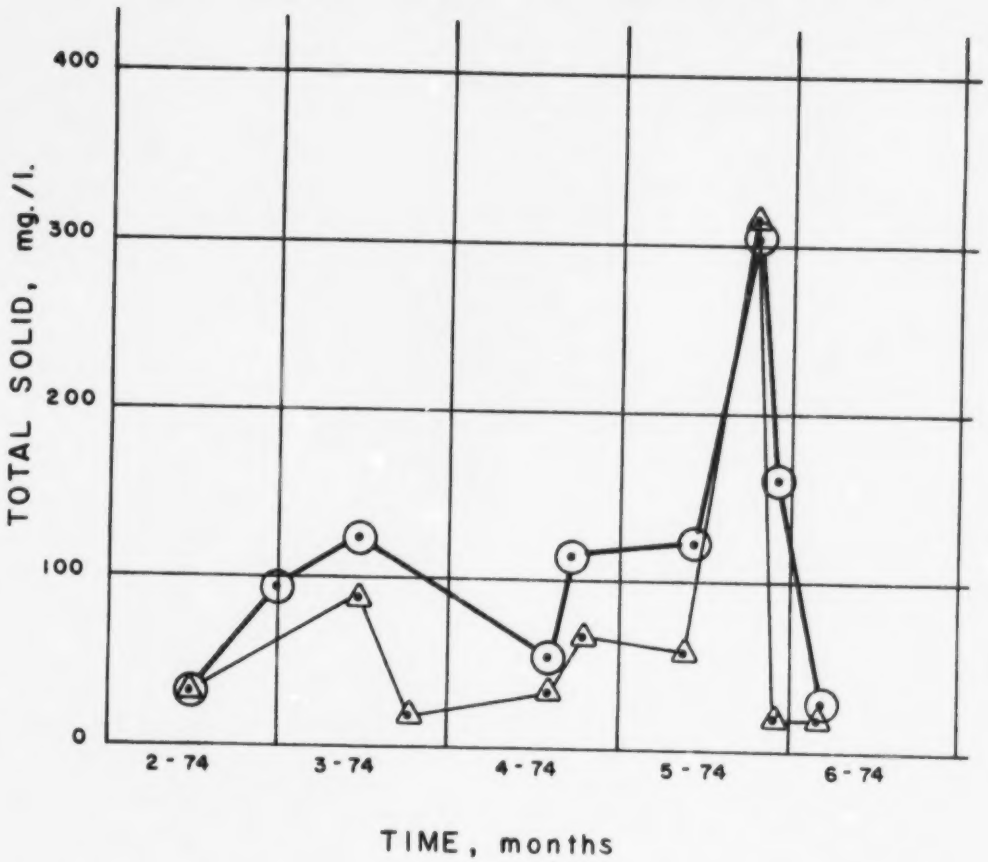
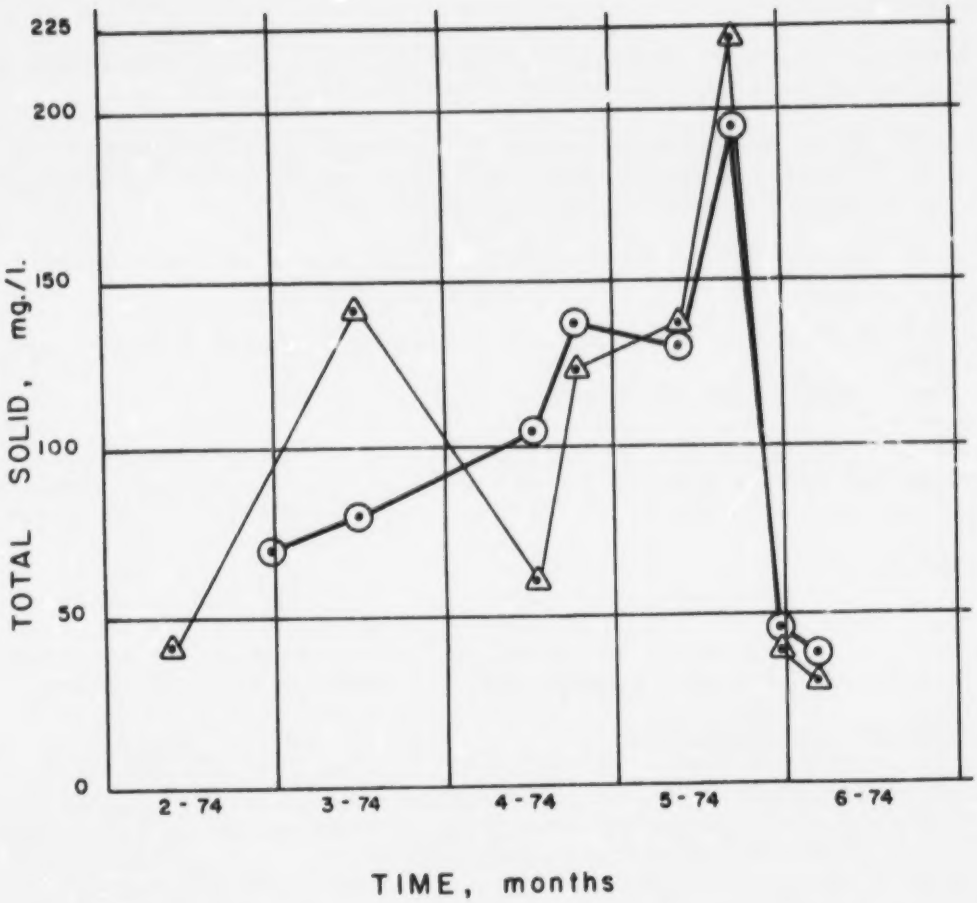


Figure 13. VARIATION OF RHOADES BRANCH COMPARED TO DICK BRANCH FOR TOTAL SOLIDS



SECTION VII

DEMONSTRATION FORMAT

As a result of this study, some guidelines are being presented for conducting the actual demonstration project.

CONSTRUCTION

The construction of the proposed sediment control structures at each site will be performed by the mine operators at no cost to the Department for Natural Resources and Environmental Protection. To comply with current mining regulations, it is necessary for the operator to build these structures in his normal operations. Each operator will submit a cost estimate relating to this work.

In addition to cost estimates submitted by the operators, cost analyses will be made from data collected at each site during the construction monitoring phase.

An observer in the field will tabulate man-hours, equipment-hours, materials and quantities for the following:

1. Site preparation, including provision of access roads, clearing and grubbing, unsuitable material disposal and topsoil stockpiling;

2. Excavation, including cut-off trenches, emergency spillway, and borrow excavations;

3. Principal spillway and discharge installations; and

4. Vegetative protection against erosion.

Costs will be computed by using prevailing wage rates and average equipment operating costs on an hourly basis. Cost of materials will be based on current unit prices for the region.

Method of work will be evaluated at each site relative to economic use of equipment, construction methods, and efficiency of the operations. For economic evaluations, all construction costs will be computed in terms of 1) unit cost of each basin; 2) acres of land disturbed; and 3) tons of coal produced.

MONITORING AND SAMPLING

The most important aspect of the demonstration project is use of reliable monitoring equipment installed so as to provide reliable data throughout the demonstration. To achieve this, automatic equipment to monitor and record turbidity, conductivity, air temperature, water temperature, pH, and stream flow should be installed in a primary station located downstream

from the debris basins. Secondary stations containing all of the above automatic equipment except air temperature monitors should also be installed upstream of the debris basins.

In order to account for the effects of weather, geologic, and topographic conditions on the demonstration, control streams in adjacent watersheds should be monitored using secondary station automatic monitoring equipment.

Grab samples should be taken at all monitoring stations ten times per year at sporadic intervals according to weather and water quality variations. These samples, taken at random times and flows, will serve as a calibration function for the monitoring stations to insure generation of reliable data as well as to provide additional water quality information.

Grab samples should be analyzed in the laboratory to determine the nature and grain size distribution of solids present and for the following parameters:

pH	Calcium
Conductivity	Magnesium
Turbidity	Manganese
Hardness	Suspended Solids
Acidity - Alkalinity	Settleable Solids
Total Iron	Sulfate

Records should be maintained concerning the progress of mining, the area of extraction, and the reclamation progress including vegetative growth. Correlation of water quality compared to amount and type of disturbed area should be made using this information.

The study areas should be aerial photogrammetrically mapped at the finalization of the mining activity to prepare complete plans showing total disturbed area, location of sediment control structures, and stream courses.

Engineering on the project should include detailed drawings and specifications for construction of the monitoring system together with supervision of construction of the monitoring systems and correlation of efforts by the mining companies and power companies.

Cross sections should be taken at each impoundment prior to mining, at 6 month intervals during the study phase, and at the completion of the monitoring to determine the rate and volume of sediment accumulation.

The final report should include all actions performed during the demonstration, their effects, an interpretation of the data obtained, and a comprehensive review of the existing regulations and practices together with recommendations, where

applicable, for improvements in all phases of debris basin use for sedimentation control.

SECTION VII

REFERENCES

1. Federal Water Quality Administration, Feasibility Study Manual Mine Water Pollution Control Demonstrations. U.S. Government Printing Office, 1970. 65 p.

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SECTION IX

APPENDICES

APPENDIX A
Jurisdictional Framework

Cognizant Authority

This study was initiated under the auspices of the Environmental Protection Agency subject to the provisions of the Water Quality Improvement Act of 1970, PL 91-224. The Act includes a subsection titled "Area Acid and Other Mine Water Pollution Control Demonstrations" which became Section 107 of the Federal Water Pollution Control Act, as amended. This section provides for the demonstration of techniques for mine drainage pollution control and directs that the Environmental Protection Agency shall require such feasibility studies as required in selecting watersheds for the purpose of the demonstration projects. Such feasibility studies are to aid the Environmental Protection Agency in selecting not only the mine drainage pollution control method(s), but also the watershed or drainage area for such application. The Act requires that the Environmental Protection Agency give preference to areas which will have the greatest public value and use.

The United States Environmental Protection Agency, Office of Research and Development, issued a grant for the mine drainage demonstration project described herein, to the Commonwealth of Kentucky, Department for Natural Resources, and Environmental Protection, Division of Reclamation. Administration of the study has been the responsibility of the Department for Natural Resources and Environmental Protection, Office of Planning and Research.

The Department for Natural Resources and Environmental Protection is a statutory unit of the Kentucky state government. The legislative basis for the Department may be found in Kentucky Revised Statutes (KRS), Chapter 224 and in numerous other chapters of the Kentucky Revised Statutes. The Department has the authority to exercise all State administrative and enforcement functions relating to the management of the Commonwealth's air, water, and land resources. (KRS 224,003, Powers and Duties of the Department).

The Department is headed by a Secretary appointed by the Governor. The Secretary is assisted by two (2) Commissioners, who in turn head two (2) Bureaus within the Department. The Bureau of Land Resources includes the following Divisions:

Reclamation

Forestry

Conservation

Special Programs

Water Resources

The Bureau of Environmental Quality includes the following Divisions:

Air Pollution

Solid Waste

Water Quality

Plumbing

Sanitary Engineering

The Secretary is advised by a seven (7) member Environmental Quality Commission. The Commission is a statutory body comprised of lay citizens appointed by the Governor for terms of four (4) years. Commission members receive no salary or other compensation for their service on the Commission. The Commission has statutory authority to advise the Secretary on any matter within his responsibility, to serve as a working forum on the environment, to recommend adoption or rejection, after public hearing, of rules or regulations proposed by the Department. (KRS 224.045, Powers and Duties of Commission).

The Kentucky General Assembly, under KRS 350, has vested in the Department for Natural Resources and Environmental Protection Division of Reclamation, the authority to regulate and control surface mining of coal to minimize or prevent its injurious effects on the people and resources of the Commonwealth. The Division of Reclamation, under the supervision of the Secretary and the Commissioner of Land Resources, has the following authority and powers relative to this project (KRS 350.050, Powers of Divisions):

1. To exercise general supervision and administration and enforcement of KRS Chapter 350 and all rules regulations, and orders promulgated thereunder;

2. To encourage and conduct investigations, research, experiments and demonstrations, and to collect and disseminate information related to surface mining.

3. To adopt, without hearing, rules and regulations with respect to the filing of reports, the issuance of permits, and other matters of procedure and administration, and;

4. To examine and pass upon all plans and specifications submitted by the operator for the method of operation, backfilling, grading, and for the reclamation of the area of land affected by his operations.

No operator in the Commonwealth of Kentucky may engage in surface mining without having first obtained from the Division of Reclamation, a permit designating the area of land affected by the operation. Permit requirements are described under KRS 350.060. (KRS 350.060, Permit Required: Contents of Application; Map; Fee; Bond).

An operator is required by KRS 350.060 (4) to submit with his permit application, a drainage plan. This plan must indicate the directional flow of water, constructed drainways, natural waterways used for drainage and the streams or tributaries receiving the discharge. In addition, the operator is required by KRS 350.090 to prepare and carry out a reclamation plan for the area of land affected by his operation. (KRS 350.090, Reclamation Plan, requirements, approval - dumping regulations.) The reclamation plan must provide for the following:

1. Cover the face of the coal with compacted non-acid bearing and non-toxic materials to a distance of at least four feet above the seam being surface mined or by a permanent water impoundment;

2. Bury under adequate fill all toxic materials, roof coal, pyritic coal, or shale determined by the Division to be acid producing, toxic or creating a fire hazard;

3. Seal off, as directed by regulations, any breakthrough of acid water creating a hazard;

4. Impound, drain or treat all runoff water so as to reduce soil erosion, damage to agricultural lands and pollution of streams and other waters;

5. Remove or bury all metal, lumber, and other refuse resulting from the operations; and

6. Revegetate with suitable seed or plant mixtures after approved regrading and soil preparation.

This project, as presented, is a demonstration of the effectiveness of debris basins for the control of sedimentation from surface mining operations in steep slope terrain. The debris basin design specifications and construction methods will be those currently used by surface mine operators in Eastern Kentucky as required and approved by the Division of Reclamation. The project is in keeping with the foregoing Kentucky Revised Statutes and will serve to demonstrate how well the intent of

the law is being carried out. The project will be conducted by the regulatory agency responsible for the enforcement of all applicable laws and thereby has all administrative authority to efficiently carry out the project in compliance with the existing laws.

Since the Department for Natural Resources and Environmental Protection, Division of Reclamation, is the grantee for the performance of the project, the demonstration will be conducted under authority established in the law (KRS 350) for the Department to encourage and conduct demonstrations related to the reclamation of lands and waters affected by surface mining.

Upon completion of the project, the Department is also charged with the dissemination of information collected during progress of demonstration.

Existing and Proposed Standards

Requirements for impoundment and treatment of runoff from surface mining operations are contained in two of the Division of Reclamations' regulations. SMR-Rg-11 requires that treatment facilities be constructed by the operator prior to the stripping operation. SRM-Rg-11 further requires that the treated discharge have: (1) pH of between 6.0 and 9.0; (2) iron concentration not in excess of 7 mg/l; (3) total alkalinity in excess of total acidity; (4) no settleable matter; (5) suspended matter not in excess of 150 JTU's, except during a precipitation event, in which case 1000 JTU's may not be exceeded. SMR-Rg-12 requires that a drainage, erosion and silt control plan for the area to be permitted be prepared by a registered professional engineer and submitted with the permit application. After approval of the drainage plan by the Division of Reclamation, silt dams are to be constructed in the drainage areas to be immediately affected by the operation. SMR-Rg-12 further requires that the height of contour surface mine silt dams not exceed 20 feet.

The engineering standards for the design of silt control structures are contained within the Division of Reclamation's "Surface Mining Sediment and Water Quality Control Handbook."

The streams involved in this demonstration are considered public waters of the Commonwealth and are, therefore, subject to the federally approved Kentucky Water Quality Standards for Interstate Waters. The water quality of the public streams, within the confines of the Commonwealth of Kentucky, is maintained through the authority vested in the Department for Natural Resources and Environmental Protection, Division of Water Quality, under Kentucky Revised Statute 224.033. The applicable standards by which said authority is administered are covered by regulation WP-4-; "Water Quality Standards for

Water of the Commonwealth", adopted July 23, 1971; and by regulation WP-6-2 "Use Classification of Waters, Treatment Requirements and Compliance", adopted November 5, 1973. Since the streams involved in this demonstration are not shown on the map "Streams of Kentucky" prepared in 1973 by the Kentucky Department of Commerce, they must meet the water quality standards set forth in WP-4-1, only at the point where they join the streams shown on the map.

It has been the policy of the Department that in the case of surface coal mining operations, compliance with the provisions of KRS 350, SMR-Rg-11 and SMR-Rg-12 would be necessary and sufficient to constitute compliance with WP-4-1 and WP-6-2. Surface mine operators are not required to obtain permits from the Division of Water Quality.

Kentucky Revised Statute, Chapter 151.250 states that no person shall commence construction of any dam across any stream or in the floodway of any stream without having first obtained a permit from the Department for Natural Resources and Environmental Protection. (KRS 151.250, Plans for dams, levees, etc., to be approved and permit issued by Division). The Department is authorized by KRS 151-250 to exempt by regulation those dams which are not of such size or type as to require approval by the Department in the interest of safety or retention of water supply. The standards by which the requirements of KRS 151.2 50 are administered, are contained in regulation DOW-Rg-2, "Design Criteria for Dams and Associated Structures", dated April 5, 1972. Regulation DOW-Rg-3, "Exemption of Non-Hazardous Sediment Structures Relating to Surface Mining," adopted December 4, 1972, exempts from obtaining a construction permit all sediment structure designs proposed in conjunction with surface mining, except those coming within the hazard classification system contained in Engineering Memorandum No. 3.

The project is in keeping with the laws and regulations concerning surface mining of coal within the Commonwealth, since operators are now required to prepare a drainage, erosion, and silt control plan; to build debris basins to Departmental specifications and to treat the drainage from the area of land affected by their operations to meet Departmental specifications. This project will serve to evaluate the effectiveness of debris basins as presently designed and constructed in the steep slope terrain of Eastern Kentucky. If it is found that the current design and construction methods are not meeting the discharge standards spelled out in SMR-Rg-11, then alternate design and construction methods will be recommended for implementation.

Since the project will be conducted under the direction of the Department for Natural Resources and Environmental Protection, all aspects of applicable regulations will be strictly observed as the Department is charged with monitoring and enforcement of surface mining operations.

The project will meet all water quality criteria and water impoundment design criteria set by the Commonwealth of Kentucky.

Site Acquisition

The site chosen for the demonstration project is located within the Commonwealth of Kentucky. The authority to acquire, restore and reclaim land as required for the project is vested in the Commonwealth of Kentucky in accordance with Kentucky Revised Statutes relating to surface mining and reclamation, KRS 350.152, 350.154, and 350.156.

Crescent Coal Company has executed lease/royalty arrangements with the mineral owners at the Dicks Fork site.

Bethlehem Steel Corporation, Bethlehem, Pennsylvania, is the owner of all surface and mineral rights at the Rhoades Branch site. Bethlehem Steel Corporation has contracted with Tackett and Manning Coal Corporation to surface mine the Rhoades Branch area.

In the normal progress of the demonstration project presented, it is not anticipated that transfer of the property will be required; especially since a formal working agreement for conducting the project has been made among the parties concerned. Acquisition of the property by purchase or under the power of eminent domain would only become necessary if severe health or safety hazards were encountered under the present ownership arrangements, or if the operators defaulted on their responsibility to restore all surface mined land.

Authority for Funding

Federal funding for this project was provided by way of a grant to the Commonwealth by the U.S. Environmental Protection Agency under authority of Section 107 of the Federal Water Pollution Act, as amended. The grant offer was made to the Commonwealth of Kentucky Department for Natural Resources and Environmental Protection, Division of Reclamation. The Department for Natural Resources and Environmental Protection, Division of Reclamat ion, is permitted to accept Federal and other funds in accordance with Kentucky Revised Statutes (KRS) 350.150, 350.163.

All sums received through the payment of fees, forfeiture of bonds, and Federal grants are placed in the State Treasury. The Department for Natural Resources and Environmental Protection, Division of Reclamation received a general fund appropriation on a bi-annual basis as approved by the Kentucky General Assembly. Funds are expended for the administration and enforcement of Kentucky Revised Statute 350 and for the reclamation of improperly reclaimed surface mined lands. Expenditure of funds is administered by the Director of the Division of

Reclamation.

Water and Mineral Rights

Property ownership and the associated holding of water and/or mineral rights for areas designated as sites for the demonstration project presented herein are not of major concern. A working agreement, by mutual affirmation, is in effect between the Commonwealth of Kentucky (grantee) and the operators of the surface mines selected as a site for the demonstration.

No transfer of property and/or rights is anticipated in the performance of the demonstration project. The working agreement entered into with each coal operator provides that the grantee will conduct the project so as not to interfere with the mining operation; likewise the operator will not interfere with the performance of the project. All streams running through the properties are considered public waters of the Commonwealth and are subject to all applicable Federal and Kentucky Water Quality Standards. The operators of the mines are subject to all existing standards concerning water quality and regulations for reclamation which apply to the workings and adjacent property covered by the boundaries stipulated in the property title, lease, permit, etc.

Crescent Coal Company owns the surface and is leasing the mineral rights at the Dicks Fork site. Bethlehem Steel Corporation owns the surface and the mineral rights at the Rhoades Branch site. No water rights are required for performance of the project since the water courses would be maintained during the project, except for the debris basins which will have a beneficial effect on the receiving stream. This is in keeping with Commonwealth of Kentucky water rights laws since surface water flowing in a stream of definite channel is not subject to ownership, in accordance with 1954 legislation (KRS 262-670 to 262.690) which states in part:

> The owner of land contiguous to public water shall have the right to such reasonable use of this water for other than domestic purposes as will not deny the use of such water to other owners for domestic purposes, or impair existing uses of other owners heretofore established, or unreasonably interfere with a beneficial use by other owners. (KRS 262.690-2).

Prevention of Future Pollution

The Department for Natural Resources and Environmental Protection, Division of Reclamation, has the authority to regulate and control the quality of drainage water emanating from surface-mined operations in the Commonwealth. The existing standards and regulations which have been established to protect

the people and resources of the Commonwealth from the injurious effects of untreated and uncontrolled surface mine operations are vested in this agency under Kentucky Revised Statutes (KRS) 350.

In addition to this regulation, the Department for Natural Resources and Environmental Protection, Division of Water Quality, is charged with safeguarding the uncontaminated waters of the Commonwealth, preventing the creation of new pollution in the waters of the Commonwealth and abating existing pollution.

The laws and regulations of the Commonwealth, in conjunction with the authority to assure compliance of these laws and regulations, as described above, assure the federal goverment that the area will not be affected by the influx of acid or other mine water pollution from nearby sources.

Table 6. WATER QUALITY DATA - DICKS FORK UPSTREAM

Date	Flow m^3/min.	pH	Conductivity Micro MHOS/cm	Turbidity J.T.U.	Settleable Solids ml/l	Alkalinity as $CaCO_3$ mg/l	Alkalinity as $CaCO_3$ kg/D	Alkalinity (phenolphthalein) mg/l	Alkalinity (phenolphthalein) kg/D	Hardness Ca mg/l	Hardness Ca kg/D	Hardness Mg mg/l	Hardness Mg kg/D
1-27-72	NR	6.4	NR	0.0	NR	6.0	---	0.0	---	4.0	---	2.9	---
7-05-72	NR	6.2	NR	0.0	NR	14.0	---	0.0	---	5.6	---	2.4	---
2-15-74	NR	7.1	46.7	0.0	0.0	6.5	---	0.0	---	4.0	---	4.4	---
3-01-74	NR	6.8	59.4	0.0	0.0	8.0	---	0.0	---	3.2	---	4.4	---
3-14-74	NR	6.6	59.0	13.0	0.5	8.0	---	0.0	---	4.0	---	2.4	---
3-28-74	NR	6.5	60.4	0.0	0.0	10.0	---	0.0	---	2.4	---	2.7	---
4-18-74	NR	7.1	59.0	0.0	0.0	2.0	---	0.0	---	4.0	---	2.9	---
4-25-74	NR	6.5	57.3	0.0	0.5	10.0	---	0.0	---	4.0	---	2.2	---
5-13-74	NR	7.0	70.0	0.0	0.0	12.0	---	0.0	---	4.0	---	2.4	---
5-23-74	NR	6.9	530.0	94.0	1.0	12.0	---	0.0	---	4.0	---	3.4	---
5-30-74	NR	6.9	67.9	0.0	0.0	14.0	---	0.0	---	4.8	---	1.5	---
6-07-74	NR	6.9	67.9	0.0	0.0	12.0	---	0.0	---	4.8	---	3.9	---

Date	Total Hardness as $CaCO_3$ mg/l	Total Hardness as $CaCO_3$ kg/D	Free Acidity mg/l	Free Acidity kg/D	Total Hot Acidity mg/l	Total Hot Acidity kg/D	Sulfate mg/l	Sulfate kg/D	Suspended Solids mg/l	Suspended Solids kg/D	Dissolved Solids mg/l	Dissolved Solids kg/D	Total Solids mg/l	Total Solids kg/D	Manganese mg/l	Manganese kg/D	Total Iron mg/l	Total Iron kg/D
1-27-72	22.0	---	0.0	---	2.0	---	14.0	---	NR	---	NR	---	NR	---	NR	---	0.15	---
7-05-72	24.0	---	0.0	---	2.0	---	13.0	---	2.0	---	NR	---	NR	---	0.0	---	0.13	---
2-15-74	24.0	---	0.0	---	2.0	---	7.0	---	15.6	---	18.8	---	34.4	---	0.0	---	0.10	---
3-01-74	24.0	---	0.0	---	2.0	---	21.0	---	55.0	---	23.0	---	78.0	---	0.0	---	0.02	---
3-14-74	24.0	---	0.0	---	4.0	---	18.0	---	2.0	---	77.0	---	79.0	---	0.0	---	0.02	---
3-28-74	17.0	---	0.0	---	4.0	---	13.0	---	5.0	---	39.0	---	44.0	---	0.0	---	0.03	---
4-18-74	22.0	---	0.0	---	2.0	---	23.0	---	11.0	---	69.0	---	80.0	---	0.0	---	0.17	---
4-25-74	20.0	---	0.0	---	4.0	---	27.0	---	31.0	---	118.0	---	149.0	---	0.0	---	0.32	---
5-13-74	20.0	---	0.0	---	4.0	---	24.0	---	0.0	---	72.0	---	72.0	---	0.0	---	0.11	---
5-23-74	24.0	---	0.0	---	3.0	---	3.0	---	6.0	---	312.0	---	318.0	---	0.0	---	1.20	---
5-30-74	18.0	---	0.0	---	1.0	---	17.0	---	46.6	---	31.4	---	78.0	---	0.0	---	0.18	---
6-07-74	28.0	---	0.0	---	2.0	---	23.0	---	32.2	---	51.2	---	83.4	---	0.0	---	0.32	---

NOTES:
NR -Not Recorded
kg/D - Kilograms per day

Table 7. WATER QUALITY DATA - DICKS FORK DOWNSTREAM

Date	Flow m^3/min.	pH	Conductivity Micro MHOS/cm	Turbidity J.T.U.	Settleable Solids ml/l	Alkalinity as $CaCO_3$		Alkalinity (phenolphthalein)		Hardness Ca		Hardness Mg	
						mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
8-17-72	NR	7.1	32.0	0.0	NR	20.0	---	0.0	---	5.4	---	1.4	---
1-16-74	NR	6.3	14.9	0.0	0.0	6.3	---	0.0	---	4.0	---	7.3	---
2-15-74	2.16	6.7	48.8	0.0	0.0	6.5	20.2	0.0	0.0	4.0	12.4	4.9	15.2
3-01-74	4.15	6.4	70.0	0.0	0.0	14.0	83.7	0.0	0.0	4.0	23.9	3.9	23.3
3-14-74	8.57	6.8	59.0	13.0	0.0	10.0	123.4	0.0	0.0	4.0	49.4	2.4	29.6
3-28-74	10.12	6.7	58.3	0.0	0.0	8.0	116.6	0.0	0.0	3.2	46.6	2.9	42.3
4-18-74	7.49	7.0	63.7	0.0	0.0	8.0	86.3	0.0	0.0	4.8	51.8	2.9	31.3
4-25-74	5.33	6.7	57.3	0.0	0.0	10.0	76.8	0.0	0.0	4.8	36.8	2.4	18.4
5-13-74	8.23	6.9	65.8	0.0	0.0	12.0	142.2	0.0	0.0	4.0	47.4	3.4	40.3
5-23-74	186.52	6.9	522.0	120.0	0.0	12.0	3223.1	0.0	0.0	4.0	1074.4	2.4	644.6
5-30-74	8.78	6.9	57.3	0.0	0.0	13.0	164.4	0.0	0.0	5.6	70.8	1.9	24.0
6-07-74	8.91	6.9	59.4	0.0	0.0	8.0	102.6	0.0	0.0	4.0	51.3	4.4	56.5

Date	Total Hardness as $CaCO_3$		Free Acidity		Total Hot Acidity		Sulfate		Suspended Solids		Dissolved Solids		Total Solids		Manganese		Total Iron	
	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
8-17-72	28.0	---	0.0	---	2.0	---	12.0	---	NR	---	NR	---	NR	---	NR	---	0.02	---
1-16-74	40.0	---	0.0	---	4.0	---	10.0	---	13.1	---	23.1	---	36.2	---	NR	---	0.10	---
2-15-74	30.0	93.3	0.0	0.0	6.0	19.7	9.0	28.0	10.8	33.6	19.7	61.3	30.5	94.9	0.0	0.0	0.10	0.31
3-01-74	26.0	155.4	0.0	0.0	3.0	17.9	18.0	107.6	42.0	251.0	NR	---	NR	---	0.0	0.0	0.00	0.00
3-14-74	20.0	246.8	0.0	0.0	3.0	37.0	20.0	246.8	0.0	0.0	92.0	1135.4	92.0	1135.4	0.0	0.0	0.01	0.12
3-28-74	20.0	291.5	0.0	0.0	4.0	58.3	12.0	174.9	0.0	0.0	21.0	306.0	21.0	306.0	0.0	0.0	0.05	0.73
4-18-74	24.0	258.9	0.0	0.0	2.0	21.6	27.0	291.2	0.0	0.0	32.0	345.1	32.0	345.1	0.0	0.0	0.23	2.48
4-25-74	22.0	168.9	0.0	0.0	1.0	23.0	22.0	168.9	22.0	168.9	44.0	337.7	66.0	506.6	0.0	0.0	0.27	2.07
5-13-74	24.0	284.4	0.0	0.0	2.0	23.7	23.0	272.6	1.0	11.9	60.0	711.1	61.0	722.9	0.0	0.0	0.08	0.95
5-23-74	20.0	5371.8	0.0	0.0	4.0	1074.4	14.0	3760.2	13.0	3491.7	307.0	82456.8	320.0	85949.4	0.0	0.0	0.91	244.4
5-30-74	22.0	273.2	0.0	0.0	1.0	12.6	16.0	202.3	4.6	58.2	13.8	174.5	18.4	232.6	0.0	0.0	0.00	0.0
6-07-74	28.0	359.3	0.0	0.0	2.0	25.7	20.0	256.6	6.2	79.5	14.0	179.6	20.2	259.2	0.4	5.1	0.2	2.6

NOTES:
NR - Not Recorded
kg/D - Kilograms per day

Table 8. WATER QUALITY DATA - HONEY FORK

DATE	Flow m³/min.	pH	Conductivity Micro MHOS/cm	Turbidity J.T.U.	Settleable Solids ml/l	Alkalinity as $CaCO_3$ mg/l	Alkalinity as $CaCO_3$ kg/D	Alkalinity (phenolphthalein mg/l	Alkalinity (phenolphthalein kg/D	Hardness Ca mg/l	Hardness Ca kg/D	Hardness Mg mg/l	Hardness Mg kg/D
2-15-74	NR	7.0	50.9	0.0	0.0	8.7	---	0.0	---	5.6	---	3.9	---
3-01-74	NR	4.6	91.2	0.0	0.0	0.0	---	0.0	---	4.8	---	4.6	---
3-14-74	NR	6.6	10.0	34.0	0.0	12.0	---	0.0	---	4.8	---	2.4	---
3-28-74	NR	NR	NR	NR	NR	NR	---	NR	---	NR	---	NR	---
4-18-74	NR	7.1	72.1	0.0	0.0	10.0	---	0.0	---	4.8	---	3.9	---
4-25-74	NR	6.5	61.6	0.0	0.0	10.0	---	0.0	---	4.0	---	2.9	---
5-13-74	NR	8.5	119.0	0.0	0.0	32.0	---	8.0	---	5.6	---	3.4	---
5-23-74	NR	6.9	400.0	135.0	0.0	10.0	---	0.0	---	4.0	---	7.4	---
5-30-74	NR	6.9	86.9	18.0	0.0	14.0	---	0.0	---	5.6	---	3.9	---
6-07-75	NR	6.7	80.5	0.0	0.0	16.0	---	0.0	---	5.6	---	2.9	---

Date	Total Hardness as $CaCO_3$ mg/l	Total Hardness as $CaCO_3$ kg/D	Free Acidity mg/l	Free Acidity kg/D	Total Hot Acidity mg/l	Total Hot Acidity kg/D	Sulfate mg/l	Sulfate kg/D	Suspended Solids mg/l	Suspended Solids kg/D	Dissolved Solids mg/l	Dissolved Solids kg/D	Total Solids mg/l	Total Solids kg/D	Manganese mg/l	Manganese kg/D	Total Iron mg/l	Total Iron kg/D
2-15-74	30.0	----	0.0	---	4.0	---	12.0	---	10.1	---	20.5	---	30.6	---	0.0	---	0.10	---
3-01-74	31.0	---	5.0	---	16.0	---	33.0	---	58.0	---	36.8	---	94.8	---	0.0	---	0.00	---
3-14-74	22.0	---	0.0	---	3.0	---	24.0	---	0.0	---	126.0	---	126.0	---	0.0	---	0.24	---
3-28-74	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---
4-18-74	28.0	---	0.0	---	2.0	---	27.0	---	0.0	---	63.0	---	53.0	---	0.0	---	0.25	---
4-25-74	22.0	---	0.0	---	4.0	---	26.0	---	0.0	---	115.0	---	115.0	---	0.0	---	0.28	---
5-13-74	28.0	---	0.0	---	0.0	---	28.0	---	0.0	---	126.0	---	126.0	---	0.0	---	0.07	---
5-23-74	20.0	---	0.0	---	3.0	---	11.0	---	144.0	---	163.0	---	307.0	---	0.0	---	0.49	---
5-30-74	30.0	---	0.0	---	1.0	---	18.0	---	100.2	---	60.0	---	160.2	---	0.0	---	0.73	---
6-07-74	26.0	---	0.0	---	4.0	---	23.0	---	15.8	---	14.0	---	29.8	---	0.0	---	0.00	---

Notes:

NR - Not Recorded
kg/D- Kilograms per day

Table 9. WATER QUALITY DATA - ROADES BRANCH DOWNSTREAM

Date	Flow m^3/min.	pH	Conductivity Micro MHOS/cm	Turbidity J.T.U.	Settleable Solids ml/l	Alkalinity as $CaCO_3$		Alkalinity (phenolphthalein)		Hardness: Ca		Hardness Mg	
						mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
1-16-74	NR	7.5	731.8	0.0	0.0	37.8	---	0.0	0.0	---	---	3.4	---
2-13-74	2.28	7.3	46.7	0.0	0.0	26.2	86.0	0.0	0.0	18.4	60.4	5.1	17.4
3-01-74	2.02	6.4	NR	NR	NR	NR	---	NR	---	NR	---	NR	---
3-14-74	7.17	7.2	89.0	15.0	0.05	16.2	167.3	0.0	0.0	7.2	74.3	3.4	35.1
3-28-74	11.72	NR	NR	NR	NR	NR	---	NR	---	NR	---	NR	---
4-18-74	4.94	7.3	102.0	0.0	0.0	16.0	113.8	0.0	0.0	8.0	56.9	3.9	27.7
4-25-74	5.65	7.0	91.2	0.0	0.0	20.0	162.7	0.0	0.0	8.0	65.1	3.4	27.7
5-13-74	5.31	7.4	163.0	0.0	0.0	32.0	244.7	0.0	0.0	11.2	85.6	5.8	44.3
5-23-74	111.48	6.8	550.0	148.0	0.0	10.0	1605.3	0.0	0.0	4.0	642.1	3.4	545.9
5-30-74	4.76	6.8	63.7	0.0	0.0	12.0	82.3	0.0	0.0	4.8	32.9	3.4	23.3
6-07-74	3.83	6.8	65.8	0.0	0.0	10.0	55.2	0.0	0.0	6.4	35.3	1.5	8.3

Date	Total Hardness as $CaCO_3$		Free Acidity		Total Hot Acidity		Sulfate		Suspended Solids		Dissolved Solids		Total Solids		Manganese		Total Iron	
	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
1-16-74	164.0	---	0.0	0.0	6.0	---	300.0	---	115.3	---	308.0	---	423.3	---	NR	---	0.3	---
2-13-74	46.0	151.0	0.0	0.0	3.0	9.8	31.0	101.8	21.8	71.6	18.8	61.7	40.6	133.3	NR	---	0.07	0.23
3-01-74	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---
3-14-74	32.0	330.4	0.0	0.0	2.0	20.6	27.0	278.8	25.0	258.1	118.0	1219.3	143.0	1476.4	0.0	0.0	0.11	1.14
3-28-74	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---
4-18-74	36.0	256.1	0.0	0.0	4.0	28.5	39.0	277.4	0.0	0.0	66.0	469.5	66.0	469.5	0.0	0.0	0.13	0.92
4-25-74	34.0	276.6	0.0	0.0	3.0	24.4	46.0	374.3	8.0	65.1	115.0	935.6	123.0	1000.7	0.0	0.0	0.20	1.63
5-13-74	52.0	397.6	0.0	0.0	4.0	30.6	44.0	336.4	2.0	15.3	135.0	1032.3	137.0	1047.6	0.0	0.0	0.32	2.45
5-23-74	24.0	3852.7	0.0	0.0	3.0	481.6	14.0	2247.4	2.0	321.1	219.0	35156.3	221.0	35477.4	0.0	0.0	0.01	1.61
5-30-74	26.0	178.2	0.0	0.0	2.0	13.7	16.0	109.7	5.6	38.4	33.4	228.9	39.0	267.3	0.0	0.0	0.0	0.0
6-07-74	22.0	121.3	0.0	0.0	1.0	5.5	25.0	137.9	18.6	102.6	10.4	57.4	29.0	159.9	0.0	0.0	0.24	1.32

NOTES:
NR -Not Recorded
kg/D - Kilograms per day

Table 10. WATER QUALITY DATA - RHOADES BRANCH UPSTREAM

Date	Flow m^3/min.	pH	Conductivity Micro MHOS/cm	Turbidity J.T.U.	Settleable Solids ml/l	Alkalinity as $CaCO_3$		Alkalinity (Phenolphthalein)		Hardness Ca		Hardness Mg	
						mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
2-13-74	NR	6.9	57.4	0.0	0.0	8.7		0.0		6.4		2.4	
3-01-74	NR	6.6	80.5	0.0	0.0	12.0		0.0		5.6		3.4	
3-14-74	NR	7.1	81.0	0.0	0.0	12.0		0.0		5.6		3.4	
3-28-74	NR	NR	NR	NR	NR	NR		NR		NR		NR	
4-18-74	NR	7.0	86.9	0.0	0.0	24.0		0.0		6.4		3.9	
4-25-74	NR	7.1	95.4	0.0	0.0	16.0		0.0		8.4		3.9	
5-13-74	NR	7.2	112.0	0.0	0.0	28.0		0.0		9.6		7.3	
5-23-74	NR	7.0	522.0	151.0	0.0	12.0		0.0		3.6		2.7	
5-30-74	NR	6.9	59.4	10.0	0.0	12.0		0.0		5.6		2.9	
6-07-74	NR	6.9	70.0	0.0	0.0	12.0		0.0		4.8		2.4	
	NR												
	NR												

Date	Total Hardness as $CaCO_3$		Free Acidity		Total Hot Acidity		Sulfate		Suspended Solids		Dissolved Solids		Total Solids		Manganese		Total Iron	
	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
2-13-74	26.0		0.0		4.0		23.0		11.7		22.3		34.0		0.0		0.05	
3-01-74	28.0		0.0		2.0		30.0		0.0		34.0		34.0		0.0		0.06	
3-14 74	28.0		0.0		2.0		28.0		15.0		74.0		89.0		0.0		0.08	
3-28-74	NR		NR		NR		NR		NR		NR		NR		NR		NR	
4-18-74	32.0		0.0		4.0		23.0		7.0		7.2		14.2		0.0		0.11	
4-25-74	37.0		0.0		4.0		30.0		12.0		121.0		133.0		0.0		0.11	
5-13-74	54.0		0.0		4.0		33.0		0.0		100.0		100.0		0.0		0.04	
5-23-74	20.0		0.0		3.0		7.0		1.0		262.0		261.0		0.0		0.79	
5-30-74	26.0		0.0		2.0		18.0		38.8		27.8		66.6		0.0		0.12	
6-07-74	22.0		0.0		2.0		23.0		2.6		3.8		6.4		0.0		0.17	

NOTES:
NR - Not Recorded
kg/D - Kilograms per day

Table 11. WATER QUALITY DATA - DICK BRANCH CONTROL STREAM

Date	Flow m^3/min	pH	Conductivity Micro MHOS/cm	Turbidity J.T.U.	Settleable Solids ml/l	Alkalinity as $CaCO_3$		Alkalinity (phenolphthalein)		Hardness Ca		Hardness Mg	
						mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
2-13-74	NR	NR	NR	NR	NR	NR	---	NR	---	NR	---	NR	---
3-01-74	NR	7.6	167.5	0.0	0.0	52.0	---	0.0	---	11.2	---	5.3	---
3-14-74	NR	7.2	112.0	12.0	0.0	26.0	---	0.0	---	8.0	---	2.9	---
3-28-74	NR	NR	NR	NR	NR	NR	---	NR	---	NR	---	NR	---
4-18-74	NR	7.8	140.0	0.0	0.0	36.0	---	0.0	---	11.2	---	3.9	---
4-25-74	NR	7.2	129.0	0.0	0.0	36.0	---	0.0	---	10.4	---	3.9	---
5-13-74	NR	8.0	178.0	0.0	0.0	52.0	---	0.0	---	12.0	---	5.3	---
5-23-74	NR	6.9	1816.0	22.0	0.0	50.0	---	0.0	---	12.8	---	5.3	---
5-30-74	NR	6.7	72.1	0.0	0.0	14.0	---	0.0	---	6.4	--	2.9	---
6-7-74	NR	6.7	70.0	0.0	0.0	16.0	---	0.0	---	6.4	---	2.4	---

Date	Total Hardness as $CaCO_3$		Free Acidity		Total Hot Acidity		Sulfate		Suspended Solids		Dissolved Solids		Total Solids		Manganese		Total Iron	
	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D	mg/l	kg/D
2-13-74	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	0.0	---	0.12	---
3-01-74	50.0	---	0.0	---	3.0	---	38.0	---	0.0	---	68.5	---	68.5	---	0.0	---	0.06	---
3-14-74	34.0	---	0.0	---	2.0	---	31.0	---	0.0	---	79.0	---	79.0	---	0.0	---	0.11	---
3-28-74	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---	NR	---
4-18-74	44.0	---	0.0	---	2.0	---	42.0	---	12.0	---	94.0	---	106.0	---	0.0	---	0.11	---
4-25-74	42.0	---	0.0	---	4.0	---	44.0	---	18.0	---	120.0	---	138.0	---	0.0	---	0.20	---
5-13-74	52.0	---	0.0	---	2.0	---	44.0	---	5.0	---	125.0	---	130.0	---	0.0	---	0.17	---
5-23-74	54.0	---	0.0	---	9.0	---	42.0	---	1.0	---	193.0	---	194.0	---	0.0	---	0.11	---
5-30-74	28.0	---	0.0	---	1.0	---	13.0	---	32.8	---	13.4	---	46.2	---	0.0	---	0.00	---
6-07-74	26.0	---	0.0	---	1.0	---	22.0	---	31.2	---	6.4	---	37.6	---	0.0	---	0.18	---

NOTES:
NR - Not Recorded
kg/D - Kilograms per day